WHO SAID THAT?

Galileo Galilei (1564-1642)

Galileo Galilei was born on 15 February 1564 in Pisa and was educated at the Camaldolese Monastery at Vallombrosa. In 1581 was sent by his father to enrol for a medical degree at the University of Pisa. Galileo never seems to have taken medical studies seriously, attending courses on his real interests which were in mathematics and natural philosophy. He left Pisa in 1585 without completing his medical degree and began teaching mathematics in Florence and later at Siena. During the summer of 1586 he taught at Vallombrosa, and in this year he wrote his first scientific book *The little balance* (*La Balancitta*) which described Archimedes' method of finding the specific gravities of substances using a balance. His reputation grew and in 1588 he received a prestigious invitation to lecture on the dimensions and location of hell in Dante's Inferno at the Academy in Florence. In 1589, Galileo was appointed to the Chair of Mathematics at the University of Pisa where he wrote *De Motu* a series of essays on the theory of motion which he never formally published. The book contains his important idea that one can test theories by conducting experiments and gave the famous example of testing falling bodies using an inclined plane to slow down the rate of descent.

In 1591, Vincenzo Galilei, Galileo's father, died and as the eldest son Galileo had to provide financial support for the rest of the family. Being Professor of Mathematics at Pisa was not well paid, so Galileo lobbied for a more lucrative post. In 1592, Galileo was appointed Professor of Mathematics at the University of Padua (the University of the Republic of Venice) at a salary of three times that he had received at Pisa. On 7 December 1592 he gave his inaugural lecture and began a period of 18 years at the University, years which he later described as the happiest of his life. At Padua his duties were mainly to teach Euclid's geometry and standard (geocentric) astronomy to medical students, who would need to know some astronomy in order to make use of astrology in their medical practice. While in Padua, Galileo publicly argued against Aristotle's view of astronomy and natural philosophy.

Portrait of Galileo Galilei by Justus Sustermans painted in 1636

At Padua, Galileo began a long-term relationship with Maria Gamba; however they never married. In 1600 their first child Virginia was born, followed by a second daughter, Livia, in the following year. In 1606 their son Vincenzo was born. Much later when his daughters were being educated at the Franciscan Convent of St Matthew outside Florence, Virginia took the name Sister Maria Celeste and Livia the name Sister Arcangela. Since they had been born outside of marriage, Galileo believed that they themselves should never marry.

In May 1609, Galileo received a report telling him about a spyglass that a Dutchman had shown in Venice. Using his own technical skills as a mathematician and as a craftsman, Galileo began to make a series of telescopes whose optical performance was much better than that of the Dutch instrument. His first telescope was made from available lenses and gave a magnification of about four times. To improve on this Galileo learned how to grind and polish his own lenses, and by August 1609 he had an instrument with a magnification of around eight or nine. Galileo immediately saw the commercial and military applications of his telescope (which he called a *perspicillum*) for ships at sea.

By the end of 1609 Galileo had turned his telescope on the night sky and began to make remarkable discoveries which he described in a short book called the *Starry Messenger*, published in Venice in May 1610. Galileo claimed to have seen mountains on the Moon, to have proved the Milky Way was made up of tiny stars, seen (although not understood their nature) the rings of Saturn, four small bodies orbiting Jupiter, and most importantly noted that the planet Venus showed phases like those of the Moon, and therefore must orbit the Sun, not the Earth. Galileo knew that all his discoveries were evidence for Copernicanism, although not a proof. Other observations made by Galileo included the observation of sunspots. He reported these in *Discourse on floating bodies* which he published in 1612 and more fully in *Letters on the sunspots*, which appeared in 1613.

The Jovian moons, with an eye to getting a position in Florence, he quickly named 'the Medicean stars'. He had also sent Cosimo de Medici, the Grand Duke of Tuscany, an excellent telescope for himself. In June 1610, only a month after his famous little book was published, Galileo resigned his post at Padua and became Chief Mathematician at the University of Pisa (without any teaching duties) and Mathematician and Philosopher to the Grand Duke of Tuscany.

In 1611, he visited Rome where he was treated as a leading celebrity. He was also made a member of the Accademia dei Lincei and this was an honour which was especially important to Galileo who signed himself 'Galileo Galilei Linceo' from this time on.

Despite his private support for Copernicanism, Galileo tried to avoid controversy by not making public statements on the issue. At a meeting in the Medici Palace in Florence in December 1613 with the Grand Duke Cosimo II and his mother the Grand Duchess Christina of Lorraine, Castelli, the successor to Galileo in the Chair of Mathematics at Pisa, was asked to explain the apparent contradictions between the Copernican theory and Holy Scripture. Castelli defended the Copernican position vigorously and wrote to Galileo afterwards telling him how successful he had been in putting the arguments. Galileo, less convinced that Castelli had won the argument, wrote Letter to Castelli to him arguing that the Bible had to be interpreted in the light of what science had shown to be true. Galileo's enemies ensured that a copy of the *Letter to Castelli* was sent to the Inquisition in Rome. However, after examining its contents they found little to which they could object. The point at issue for the Inquisition was whether Copernicus had simply put forward a mathematical theory which enabled the calculation of the positions of the heavenly bodies to be made more simply or whether he was proposing a physical reality.

In 1616 Galileo wrote a letter to the Grand Duchess Christina of Lorraine which vigorously attacked the followers of Aristotle. In this work, he argued strongly for a non-literal interpretation of Holy Scripture when the literal

interpretation would contradict facts about the physical world proved by mathematical science. In this Galileo stated quite clearly that for him the Copernican theory is not just a mathematical calculating tool, but is a physical reality: ''*…I hold that the Sun is located at the centre of the revolutions of the heavenly orbs and does not change place, and that the Earth rotates on itself and moves around it. Moreover … I confirm this view not only by refuting Ptolemy's and Aristotle's arguments, but also by producing many for the other side, especially some pertaining to physical effects whose causes perhaps cannot be determined in any other way, and other astronomical discoveries; these discoveries clearly confute the Ptolemaic system, and they agree admirably with this other position and confirm it*'' . Pope Paul V then ordered that Sacred Congregation of the Index decide on the Copernican theory. The cardinals of the Inquisition met on 24 February 1616 and took evidence from theological experts. They condemned the teachings of Copernicus and the decision was conveyed to Galileo, who had not been personally involved in the trial. Galileo was forbidden to hold Copernican views.

Maffeo Barberini, who was an admirer of Galileo, was elected as Pope Urban VIII and invited Galileo to papal audiences on six occasions and led Galileo to believe that the Catholic Church would not make an issue of the Copernican theory. Galileo, therefore, decided to publish his views believing that he could do so without serious consequences from the Church. By this stage in his life Galileo's health was poor and it took him 6 years to complete his famous *Dialogio*. Galileo attempted to obtain permission from Rome to publish the Dialogue in 1630, but this did not prove easy. Eventually he received permission from Florence, not Rome. In February 1632 Galileo published *Dialogue concerning the two chief systems of the world: Ptolemaic and Copernican* and shortly after its publication the Inquisition banned its sale and ordered Galileo to appear in Rome before them. Galileo's accusation at the trial which followed was that he had breached the conditions laid down by the Inquisition in 1616. However, a different version of this decision was produced at the trial rather than the one Galileo had been given at the time. When found guilty and after making his abjuration of heliocentricity, he famously uttered the apocryphal words to himself ''*Epur si muove*'' (And yet it does move).

Galileo was condemned to lifelong imprisonment, but the sentence was carried out somewhat sympathetically and it amounted to house arrest rather than a prison sentence. In 1634, he suffered a severe blow when his daughter Virginia, Sister Maria Celeste, died. She had been a great support to her father through his illnesses and Galileo was shattered and could not work for many months. When he did manage to restart work, he began to write *Discourses and mathematical demonstrations concerning the two new sciences*. After Galileo had completed work on the *Discourses* it was smuggled out of Italy, and taken to Leyden in Holland, where it was published. It was his most rigorous mathematical work which treated problems on impetus, moments, and centres of gravity. In the *Discourses* he developed some of his most famous and enduring mathematical ideas, such as on the motion of objects on an inclined plane, the acceleration of free-falling bodies, as well as the movement of the pendulum.

Galileo died in Arcetri (near Florence) on 8 January 1642. It was a sad end for so great a man to die condemned of heresy. His will indicated that he wished to be buried beside his father in the family tomb in the Basilica of Santa Croce, but his relatives rightly feared that this would provoke opposition from the Church. His body was concealed and only placed in a fine tomb in the church in 1737 by the civil authorities against the wishes of many in the Church. On 31 October 1992, 350 years after Galileo's death, Pope John Paul II gave an address on behalf of the Catholic Church in which he admitted that errors had been made by the theological advisors in the case of Galileo. He declared the Galileo case closed, but he did not admit that the Church was wrong to convict Galileo on a charge of heresy because of his belief that the Earth rotates round the sun.

RECOMMENDED READING

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